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Development of High Power Lasers for Materials Interactions

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Development of High Power Lasers for Materials Interactions

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Paper

The Lawrence Livermore National Laboratory (LLNL) has a long history of developing high power lasers for use in basic science and applications. The Laser Science and Technology Program (LS&T) at LLNL supports advanced lasers and optics development both for the National Ignition Facility (NIF) as well as for high power lasers and optics technology for a broader range of government, military and industrial applications.

The NIF laser is currently under construction with the first of the 192 beamlines being activated. When finished NIF will have an output energy of 2 MJ at 351 nm. This system will be used for studies of high energy density physics, equation of state and inertial confinement fusion.

It is now generally acknowledged that the future of laser missile defense lies with solid state lasers. The leading laser technology for theater missile defense is under development within the Laser Science and Technology Program (LS&T) and funded by the US Army SMDC. This high average power technology is based on a solid state laser operated in a heat capacity mode. In the concept the heat producing lasing cycle is separated in time from the cooling cycle thus reducing thermal gradients and allowing significantly greater average output power. Under the current program, an LLNL developed laser has achieved a record setting 13 kW of average power in 20 second duration bursts. We have also performed target lethality experiments showing a previously unrecognized advantage of a pulsed laser format. The LLNL work is now focused on achieving improved output beam quality and in developing a 100 kW output with diode pumping of a large aperture crystal gain medium on a compact mobile platform.

The Short Pulse Laser Group of LS&T has been developing high power short pulse laser systems for a number of applications. Of great importance is petawatt (10^{12} Watt) and greater power output to support experiments on the NIF. We are developing a system of 5 kJ class output and 5 to 10 ps pulse duration for generating intense radiation for radiography, particle beam generation and eventually for a new class of fusion experiments call fast ignition. We have also built a record setting 50 watts of average output from a picosecond class laser and are using this technology for materials processing such as fine hole drilling and safe cutting of munitions.

The laser science and technology program has developed and deployed a laser guide star on the Lick telescope on Mt. Hamilton and most recently on the Keck telescope in

Hawaii. Our current development work in this area is focused on developing a much more compact all solid state diode pumped laser fiber system.

Finally in a program originally initiated by DARPA we have developed a phase conjugated Nd:glass laser system with record setting performance and successfully deployed it for Navy and Air Force satellite imaging applications and have more recently successfully transferred it to industry for use in an emerging technology called laser peening. This laser technology is capable of 25 J to 100 J per pulse, 10 ns to 1000 ns pulse duration, 5 Hz laser. The technology has been industrially deployed and is proving to be highly effective in generating high intensity shocks that induce compressive residual stress into metal components. The compressive stress retards fatigue and stress corrosion cracking and is proving to extend the lifetime of high value components by factors of ten. This processing adds lifetime, enhances safety and can improve performance of aircraft systems. Laser peening is now being evaluated to reduce the weight of aircraft and may play a major role in the future combat system and its air transport by enabling lighter craft, longer range and greater payload. The laser peening technology is also being moved forward in NRC license application as the means to eliminate stress corrosion cracking for Yucca Mountain nuclear waste disposal canisters as well as a broad range of other applications.